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(71) Applicant: Seibu Giken Co., Ltd.
Koga-shi, Fukuoka (JP)

(72) Inventor: Okano, Hiroshi
Fukuoka-shi, Fukuoka (JP)

(74) Representative:
Johnson, Terence Leslie
Edward Evans & Co.,
Clifford's Inn,
Fetter Lane
London EC4A 1BX (GB)

(54) Dehumidifier

(57) The invention relates to a dehumidifying apparatus comprising an adsorbing element, having a plurality of groups of passages (2, 3) that are separated from each other and wherein heat can be conducted between each other said plurality of groups of passages, a moisture adsorbent (6, 7) on the inner surface of one group of the passages of said adsorbing element, in use in a dehumidifying process of gas to be treated, said gas to be treated flowing in one group (2) of the passages of said adsorbing element and at the same time a cooled gas to evaporate the water remaining in the other group (3) of passages flowing in the other group of passages, and in the process of desorbing said moisture adsorbent a high temperature reactivating fluid remains in the other group of the passages of said adsorbing element flowing.

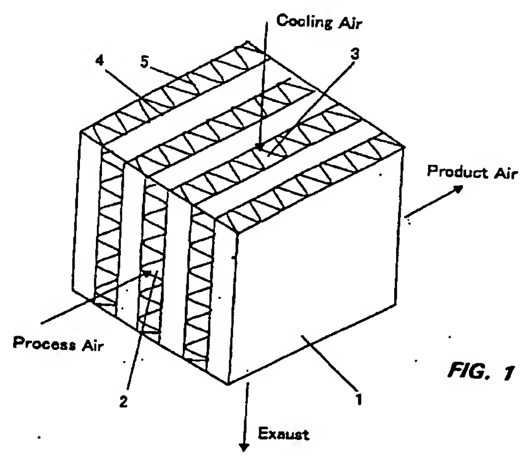

FIG. 1

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Description

[0001] The invention relates to a dehumidifier used for a dehumidification air conditioner.

[0002] Conventionally, as for a dehumidifier, freezing and adsorption types have become widespread, and as for a dry type it has been the honeycomb rotor with fixed silica gel which has spread in recent years, as an adsorption type.

[0003] A dry type dehumidifier using such a honeycomb rotor is suitable as equipment which supplies air of low dew point.

[0004] However, the dew point of output air of the dry type dehumidifier is limited for the following reason.

[0005] The dry type dehumidifier using a honeycomb rotor generates adsorption heat, and adsorbent, such as silica gel adsorbs moisture in the processed air, which should be dehumidified.

[0006] This is because the temperature of processed air goes up and the relative humidity falls, though dew point (absolute humidity) is high.

[0007] For low relative humidity, dehumidification will thus be difficult.

[0008] To improve dehumidification performance, processed air would thus need to be pre-cooled.

[0009] From such a problem, the technology disclosed in Japanese Laid-Open Patent Showa 62-68520, for example, was developed.

[0010] That is, a sensible heat exchange function is given to a honeycomb rotor, and it is made to adsorb while an air flow removes adsorption heat.

[0011] The technology indicated by the above-mentioned specification is related to the equipment which adsorbs the moisture in processed air, and cooling processed air by the atmosphere.

[0012] Such equipment is effective in avoiding a fall of the adsorption effect by generation of adsorption heat.

[0013] However, the temperature of a cooling medium rises with adsorption heat, and such equipment has the problem that prevention of a fall of the adsorption effect is still not effective.

[0014] It is an object of the invention to seek to solve the above problems and provide a dehumidifier with a high dehumidification capability.

[0015] According to the invention there is provided a dehumidifying apparatus comprising an adsorbing element, having a plurality of groups of passages that are separated from each other and wherein heat can be conducted between each other said plurality of groups of passages, a moisture adsorbent on the inner surface of one group of the passages of said adsorbing element, in use in a dehumidifying process of gas to be treated, said gas to be treated flowing in one group of the passages of said adsorbing element and at the same time a cooled gas to evaporate the water remaining in the other group of passages flowing in the other group of passages, and in the process of desorbing said moisture adsorbent a high temperature reactivating fluid remains in the other group of the passages of said adsorbing element flowing.

[0016] Thus using the invention it is possible to provide for adsorbing heat of adsorbent in one passage of a dehumidifying element, which is reduced by vapour heat of water in another passage of the dehumidifying element.

[0017] In particular there is provided an adsorbing element, having plural groups of passages that are separated from each other and wherein heat can be conducted between each other said plural groups of passages, a moisture adsorbent being on the inner surface of one group of the passages of said adsorbing element, in the dehumidifying process of the air to be treated, said air to be treated flowing in one group of the passages of said adsorbing element and at the same time a cooled air to evaporate the water remaining in the other group of passages flowing in the other group of passages, and in the process of desorbing said moisture adsorbent a high temperature reactivating fluid such that water remains in the other group of the passages of said adsorbing element flowing.

[0018] A dehumidifier embodying the invention is hereinafter described, by way of example, with reference to the accompanying drawings.

Fig. 1 is a perspective schematic view of an apparatus showing the principle in an adsorption process;

Fig. 2 is a perspective schematic view of apparatus for a desorption process;

Fig. 3 shows to an enlarged scale a principal part of an adsorption element of the apparatus of Figs. 1 and 2;

Fig. 4 shows a view similar to that of Fig. 3 of a moisture adsorbent element of a dehumidifying apparatus.

Fig. 5 is a view similar to Fig. 4 of an alternative embodiment of element;

Fig. 6 is a perspective view of an adsorption rotor of dehumidifying apparatus according to the invention;

Fig. 7 shows the rotor of Fig. 6 showing support rollers by which it may be rotated in use;

Fig. 8 shows a schematic view of flows through the rotor of Figs. 6 and 7; and

Fig. 9 shows schematically a third embodiment of rotor used in apparatus according to the invention.

[0019] Referring to Figs. 1 and 2 firstly, there is shown adsorption element 1 of a cross flow type which

has a first passage 2 to which processed air flows, and a second passage 3 to which cooling air flows. That is plane sheets 4 and wavelike sheets 5 are assembled in a pile, and laminating is carried out in such a way that each layer is shifted by a unit of 90 degrees in relation to the next layer.

[0020] A desorption process is shown in Fig. 2, the removal air which washes away the air containing the moisture by which the desorption was carried out, passes through the first passage 2.

[0021] Heating fluid, such as steam, hot and wet air of temperature 60°C and relative humidity 90% or hot water of temperature 60°C is passed through the second passage 3.

[0022] As shown in Fig. 3 moisture adsorbent 6, such as silica gel, ion-exchange resin or hydrophillic zeolite, is fixed to the inside or to boundary walls of the first passage 2.

[0023] As shown in Fig. 4, moisture adsorbent 7, such as silica gel, ion-exchange resin or hydrophillic zeolite, is fixed to the inside or to the boundary walls of the second passage 3, as material for holding water.

[0024] Alternatively, the inside or boundary surfaces of the second passage 3 are made into a hydrophillic medium, instead of fixing moisture adsorbent 7, by alumite processing, or by making a fine unevenness. Or, again as shown in Fig. 5, a non woven fabric 7' can be secured as by being pasted onto the inner or boundary wall of the second passages 3, or yet again, a porosity or porous cement can also be applied.

[0025] The adsorption element 1, constructed as hereinbefore described, dehumidifies as follows.

[0026] With reference to Fig. 1, the moisture adsorbent 7 inside the second passage 3 is wetted with water initially.

[0027] Next, processed air, for example, an outer air, is passed to the first passage 2. Cooling air, for example, an outer air, is passed to the second passage 3.

[0028] By this action, with it, the moisture adsorbent 6 in the first passage 2 adsorbs, and the moisture in the processed air is dried and becomes dry air, and it leaves the first passage 2, as such.

[0029] At this time, the moisture adsorbent 6 generates heat of adsorption. The adsorption heat is conducted to the second passage 3, heats the moisture adsorbent 7, and carries out the desorption of the water by which moisture adsorbent 7 was adsorbed.

[0030] Cooling air is flowing to the second passage 3, and the moisture which is released or desorbed from the moisture adsorbent 7 is discharged to the outside. That is, the moisture adsorbent 7 is cooled by desorption heat and the cooling air. Thus heat which acted in this way and which derived from the moisture adsorbent 6 in the first passage 2 is taken by the second passage 3.

[0031] The temperature in the first passage 2 is thus maintained low, and the dehumidification effect becomes high.

[0032] When the moisture adsorbent 6 in the first passage is saturated with water, or nearly so, and dehumidification becomes impossible, desorption is performed. In this case, as shown in Fig. 2, heating fluid is passed to the second passage 3.

[0033] As heating fluid, such a fluid is used as remains water in the second passage 3 after passing therethrough, i.e. a 50-100°C hot water, steam, or warm air of high humidity.

[0034] Here, warm air of high humidity means the temperature is between 50-100°C and the high relative humidity that which produces dew or condensation in the second passage 3.

[0035] By passing heating fluid in the second passage 3, the temperature of the second passage 3 rises by the sensible heat which this heating fluid has, and this sensible heat is transmitted to the first passage 2, and the desorption of the moisture with which the moisture adsorbent 6 in the first passage 2 was adsorbed, is carried out. At this time, by passing removal air to the first passage 2, the moisture by which the desorption was carried out will vaporise as steam, and will be discharged.

[0036] When the desorption of the moisture adsorbent 6 in the first passage 2 is fully carried out, the flow of the heating fluid to the second passage 3 is stopped.

[0037] Monitoring of whether full desorption of the moisture adsorbent 6 in the first passage 2 is effected is performed by measuring the humidity of the exit air from the first passage 2.

[0038] If the humidity of the exit air from the first passage 2 fully falls, it can be assumed that the desorption of the moisture adsorbent 6 was fully carried out. Or when the time during which the heating fluid is passed to the second passage 3 reaches a predetermined time, a judgement can be made as to whether the desorption of the moisture adsorbent 6 has been fully carried out. Or an assessment can be made by detecting the difference of the entrance temperature of the heating fluid, and the exit temperature thereof, passed to and from the second passage 3, particularly when a predetermined temperature difference has been reached.

[0039] When the desorption of the moisture adsorbent 6 in the first passage 2 is completed, the inner or boundary wall of the second passage 3 will be wetted by heating fluid.

[0040] Therefore, it is not necessary to wet the moisture adsorbent 7 of the second passage 3 before a subsequent dehumidification process.

[0041] Dehumidification of a room can be done by repeating operation of above-mentioned dehumidification and desorption in turn.

[0042] Hereinafter, the second embodiment of the invention is explained.

[0043] The equipment of the second embodiment enables it to perform adsorption and desorption continuously by assembling a plurality of adsorption elements

1 in an annular array in a rotor, Fig. 6 being a perspective view of that adsorption rotor 8.

[0044] Fig. 7 is a perspective diagram of a dehumidifier of the invention utilising the rotor 8 of Fig. 6.

[0045] Fig. 8 is an air flow chart showing the flow of the air of the dehumidifier of Fig. 7.

[0046] In Fig. 6, although the adsorption rotor 8 has twelve adsorption elements 1, since all adsorption elements are the same, only one adsorption element 1 is illustrated, and other adsorption elements are omitted for clarity.

[0047] All the adsorption elements 1 have a plane sheet 4 and a wavelike sheet 5, as in Figs. 1 - 4.

[0048] A large diameter ring 9 and a small diameter ring 10 are each made of a suitable material such as a steel material and each having an "L" shape section.

[0049] All the adsorption elements 1 are combined annularly by fixing their upper and lower sides between the large and small diameter rings 9 and 10.

[0050] The adsorption rotor 8 is rotatably supported on a roller arrangement 11, Fig. 7. Although, as for the roller arrangement 11, only two pairs of rollers are illustrated in Fig. 7, in order to support the rotor properly for rotation, three pairs of rollers are required, one pair of rollers 11 being hidden behind a desorption inlet chamber 12 in Fig. 7 and is thus not shown. The adsorption rotor 8 is driven by a motor (not shown).

[0051] The desorption inlet chamber 12 is formed so that it runs on the upper (as viewed) surface of the adsorption rotor 8, and hot desorption gas, such as steam, is passed here.

[0052] The desorption inlet chamber 12 is fixed to a frame (not shown) which supports the whole apparatus.

[0053] The desorption inlet chamber 12 covers about a quarter of the adsorption rotor 8 upper surfaces.

[0054] The desorption exit or exhaust chamber 13 is formed opposite the desorption inlet chamber 12. That is, desorption gas which entered from the desorption inlet chamber 12 passes through the adsorption rotor 8, and then passes into the desorption outlet chamber 13. In Fig. 7, a part of desorption outlet chamber 13 is shown.

[0055] A desorption exhaust chamber 14 is formed so that it runs along the inside of the adsorption rotor 8, and covers about a quarter of adsorption rotor 8. The desorption exhaust chamber 14 is formed in the same angular position as the desorption inlet chamber 12, and is fixed to the frame (not shown) which supports the whole apparatus.

[0056] Thus the outer air which entered from the perimeter of the adsorption rotor 8 is discharged from the desorption exhaust chamber 14.

[0057] With reference to Figs. 7 and 8, a cooling inlet chamber 15 is formed so that it runs on the upper surface of the adsorption rotor 8, and it covers about three quarters of the adsorption rotor 8 upper surfaces.

[0058] A cooling outlet chamber 16 is formed so that it runs on the undersurface of the adsorption rotor 8, and it covers about three quarters of the adsorption rotor 8 undersurfaces.

[0059] The cooling inlet chamber 15 and the cooling outlet chamber 16 are shown with dotted lines in Fig.7.

[0060] The cooling inlet chamber 15 and the cooling exhaust chamber 16 are opposite each other, in the embodiment.

[0061] Therefore, the outer air which is processed air which entered from the cooling inlet chamber 15 passes the adsorption rotor 8, and is discharged from the cooling exhaust chamber 16.

[0062] The cooling inlet chamber 15 and the cooling exhaust chamber 16 are fixed to the frame (not shown) which supports the whole apparatus.

[0063] With reference to Fig. 8, a processed air inlet chamber 17 is formed so that it runs on the inside of the adsorption rotor 8, and it covers about three quarters of the adsorption rotor 8 inside surfaces.

[0064] Therefore, the air which entered from the processed air inlet chamber 17 passes the adsorption rotor 8, and is discharged from the perimeter of the adsorption rotor 8 as product air.

[0065] The processed air inlet chamber 17 is fixed to the frame (not shown) which supports the whole apparatus.

[0066] The second embodiment of the invention is made as described above, and its operation is described below.

[0067] First, operation of the adsorption element 1 in the position which counters the desorption entrance inlet chamber 12, the desorption outlet chamber 13, and the desorption exhaust game bar 14 is explained.

[0068] Desorption gas, such as steam or air of high temperature and high humidity, is passed to the desorption inlet chamber 12.

[0069] The temperature of desorption gas is desirably about 50-100°C.

[0070] Then, desorption gas passes through the second passage 3 of the adsorption element 1 which is located opposite the desorption inlet chamber 12, and it is discharged from the desorption outlet chamber 13, heating the first passage 2.

[0071] Moisture is taken up by the adsorbent in the second passage 3 while the desorption of the moisture with which the adsorbent in the first passage 2 was adsorbed by this is carried out.

[0072] That is, the temperature of desorption gas is 100°C or less, and contains much moisture.

[0073] Therefore, while desorption gas has passed through the inside of the second passage 3, the heat moves to the first passage 2, the temperature falls, and dew condensation arises in the second passage 3.

[0074] Desorption of the adsorbent in the first passage 2 is explained in more detail hereinafter.

[0075] While outer air is passed through the first passage 2, it is heated by the heat from the second passage 3.

[0076] The desorption of the adsorbent in the first

passage 2 is carried out by this heating, and the moisture by which the desorption was carried out is discharged from the desorption exhaust chamber 14.

[0077] Operation of the adsorption element 1 that is facing with the cooling inlet chamber 15, the cooling exhaust chamber 16, and the processed air inlet chamber 17 is explained hereinafter.

[0078] Outer or ambient air is passed to the cooling inlet chamber 15 and the processed air inlet chamber 17.

[0079] Then, the outer air which entered from the processed air inlet chamber 17 goes into the first passage 2.

[0080] The outer air sent to the first passage 2 has moisture adsorbed by the adsorbent in the first passage 2.

[0081] The outer air is dried to become product air, by the first passage 2, and leaves from the first passage 2.

[0082] At this time, the adsorbent in the first passage 2 generates adsorption heat. The adsorption heat generated is transmitted to the second passage 3, and raises the temperature of the second passage 3.

[0083] The inside of the second passage 3 has dew from the moisture which the desorption gas has, or the adsorbent in the second passage 3 contains moisture.

[0084] Therefore, the water which condensed in the second passage 3 is evaporated or desorpted.

[0085] At this time, the temperature in the second passage 3 falls owing to evaporation heat or desorption heat.

[0086] The outer air which entered the second passage 3 through the cooling inlet chamber 15 reduces the temperature of the second passage 3 while it drives out moisture produced by evaporation or desorption, and it exits from the second passage through the cooling exhaust chamber 16.

[0087] The adsorption heat generated when the moisture contained in an outer air within the first passage 2 is adsorbed is taken up by the desorption heat or evaporation heat in the second passage 3, and a temperature rise of the first passage 2 is suppressed.

[0088] For this reason, a fall of the adsorption performance by the temperature rise accompanied by adsorption can be suppressed, and the adsorption performance of the adsorbent in the first passage 2 can be maintained high.

[0089] A third embodiment of the invention is shown in Fig. 9. This third embodiment is fundamentally the same in construction as the equipment of the second above-mentioned embodiment, but has a greater thermal energy efficiency as compared with the equipment of the second embodiment.

[0090] The third embodiment contains the operational elements of the second embodiment, and these elements are given the same reference numbers as that of the second embodiment and a duplicate explanation is therefore omitted for brevity.

[0091] Heating/humidification equipment 18 is connected to the exit of the desorption outlet chamber 13, and applies the heat and moisture which were lost while passing the second passage 3.

[0092] The outlet of heating/humidification equipment 18 is connected to the desorption inlet chamber 12.

[0093] The cross-flow-type heat exchange equipment 19 of Fig. 9 is arranged so that heat exchange may be carried out between the high temperature air or desorption exhaust chamber 14 outlet, and an outer air.

[0094] An outer air is heated by the high temperature air of desorption exhaust chamber 14 outlet, and passes into the first passage 2 of the adsorption element 1 through the desorption entrance chamber 20.

[0095] The equipment of this third embodiment performs for dehumidification like the second embodiment 2. Since waste heat is recovered by the cross-flow-type heat exchange equipment 19 and is applying only the heat and moisture which were lost with heating/humidification equipment 18, the equipment of the third embodiment has a high thermal energy efficiency.

[0096] Embodiments 1 - 3 are an example of use of desorption fluid by which water remains in the second passage 3.

[0097] It is made to dehumidify, carrying out spraying of the water into the second passage 3 in a dehumidification process as another means, the same effect as the equipment of embodiments 1 - 3 can be acquired.

[0098] Since the dehumidifier of this invention is constituted like the above, the adsorption heat which occurred in the first passage is taken with the evaporation heat and the desorption heat of the second passage during operation, and since a rise of the temperature of the first passage is small, it can show an effective performance of the adsorbent in the first passage.

[0099] For this reason, a high adsorption performance can be demonstrated.

[0100] Furthermore, the dehumidifier of this invention can be continuously dehumidified by arranging an adsorption element annularly like the second embodiment.

[0101] Moreover, the dehumidifier of this invention can collect the waste heat of a desorption exhaust gas like the third embodiment, and can raise thermal energy efficiency for a desorption exhaust gas re-heating and by re-humidifying.

[Figure 1]

[0102] The perspective diagram showing the principle in the adsorption process of the dehumidifier of this invention.

[Figure 2]

[0103] The perspective diagram showing the principle in the desorption process of the dehumidifier of this invention.

[Figure 3]

[0104] The enlargement of the adsorption element used for the dehumidifier of this invention.

[Figure 4]

[0105] The enlargement of the adsorption element used for the dehumidifier of this invention.

[Figure 5]

[0106] The enlargement of the adsorption element used for the dehumidifier of this invention.

[Figure 6]

[0107] The perspective diagram of the adsorption rotor used for the dehumidifier of the second embodiment of this invention.

[Figure 7]

[0108] The perspective diagram of the dehumidifier of the second embodiment of this invention.

[Figure 8]

[0109] The air flow figure showing the flow of the air of the dehumidifier of the second embodiment of this invention.

[Figure 9]

[0110] The air flow figure showing the flow of the air of the dehumidifier of the third embodiment of this invention.

[Explanation of symbols]

[0111]

1	Adsorption Element
2	First Passage
3	Second Passage
4	Plane Sheet
5	Wavelike Sheet
6 and 7	Moisture Adsorbent
8	Adsorption Rotor
9	Large Ring
10	Small Ring
11	Roller
12	Desorption Inlet Chamber
13	Desorption Outlet Chamber
14	Desorption Outlet Chamber
15	Cooling Inlet Chamber
16	Cooling Exhaust Chamber
17	Processed Air Inlet Chamber
18	Heating/Humidification Equipment
19	Cross-Flow-Type Heat Exchange Equipment
20	Desorption Entrance Chamber

Claims

1. A dehumidifying apparatus comprising an adsorbing element, having a plurality of groups of passages (2, 3) that are separated from each other and wherein heat can be conducted between each other said plurality of groups of passages, a moisture adsorbent (6, 7) on the inner surface of one group of the passages of said adsorbing element, in use in a dehumidifying process of gas to be treated, said gas to be treated flowing in one group (2) of the passages of said adsorbing element and at the same time a cooled gas to evaporate the water remaining in the other group (3) of passages flowing in the other group of passages, and in the process of desorbing said moisture adsorbent a high temperature reactivating fluid remains in the other group of the passages of said adsorbing element flowing.

2. A dehumidifying apparatus comprising an adsorbing element, having a plurality of groups of passages that are separated from each other and wherein heat can be conducted between said plurality of groups of passages, a moisture adsorbent being on the inner surface of one group of the passages of said adsorbing element, in use in a dehumidifying process air to be treated, said air to be treated flowing in one group of the passages of said adsorbing element and at the same time water being poured in the other group of the passage and cooled air being flowed to evaporate said water, and in the process of desorbing said moisture adsorbent a high temperature reactivating fluid flowing in the other group of the passages of said adsorbing element.

3. A dehumidifying apparatus according to Claim 1 or 2, in which a plurality of dehumidifying adsorbing elements are annularly arranged, whereby to carry out a dehumidifying process and a reactivating process by the reactivate adsorbing element, and to carry out dehumidification continuously.

4. A dehumidifying apparatus according to Claim 1 or 2, in which atmospheric air flows in one of the groups of the passages of the adsorbing element in

the process of desorbing through a heat exchanger to proceed the heat exchange between the exhaust air after desorbing and the atmospheric air.

5. A dehumidifying apparatus according to Claim 1 or 2, in which reactivating fluid being flowed in the adsorbing element at the reactivating process is heated and humidifies again and is flowed again in the adsorbing element.

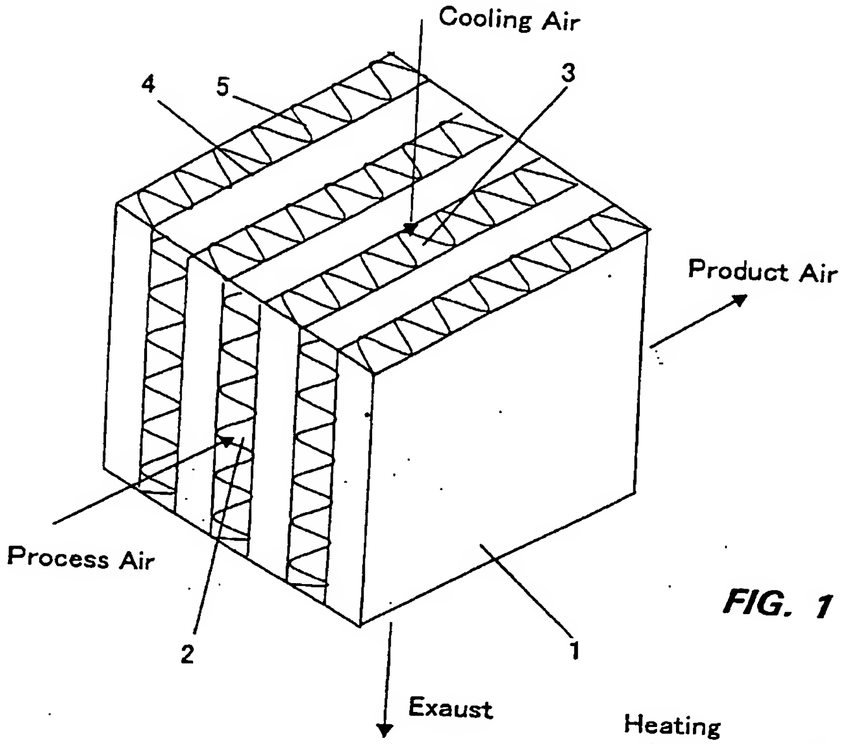
Cooling Air
4
5
3
Product Air
Process Air
2
1
Exaust

FIG. 1

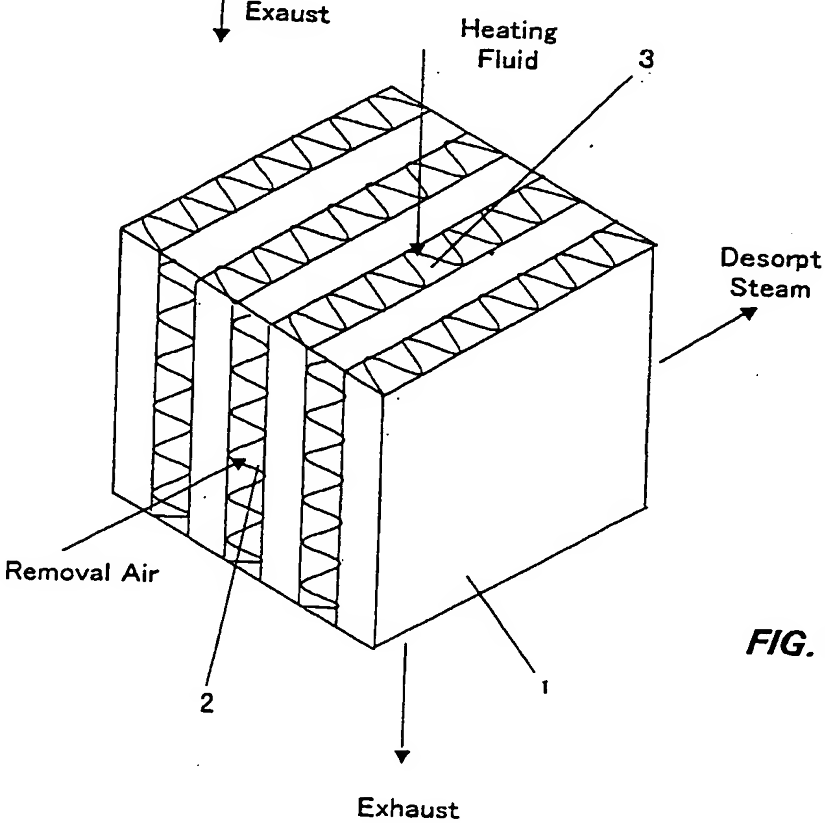
Heating Fluid
3
Desorpt Steam
Removal Air
2
1
Exhaust

FIG. 2

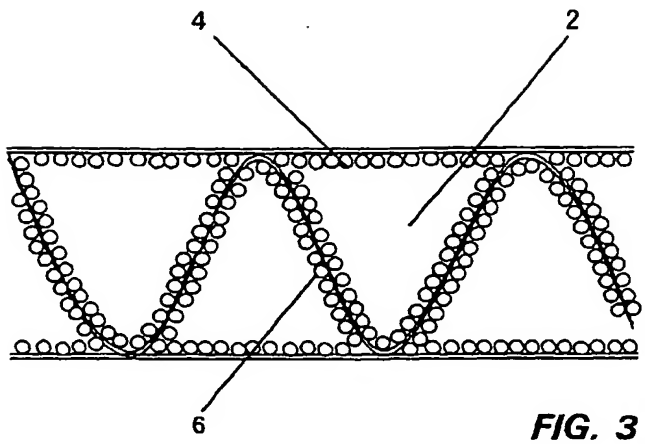

FIG. 3

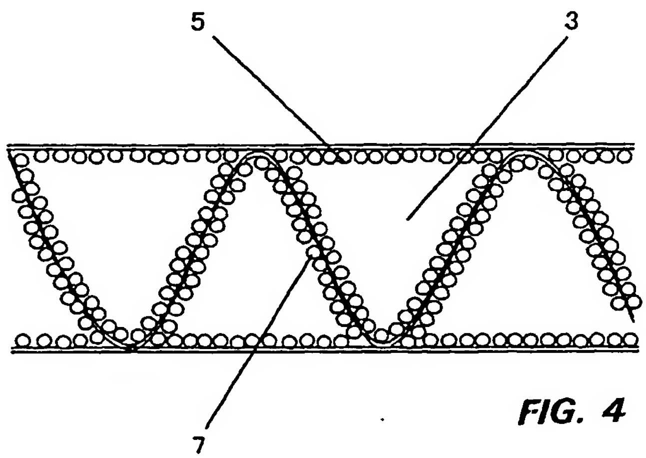

FIG. 4

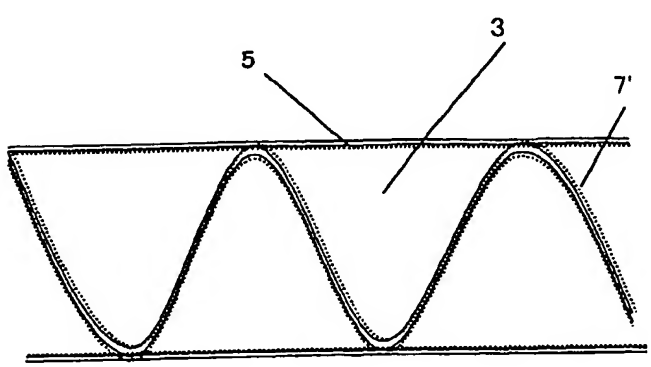

FIG. 5

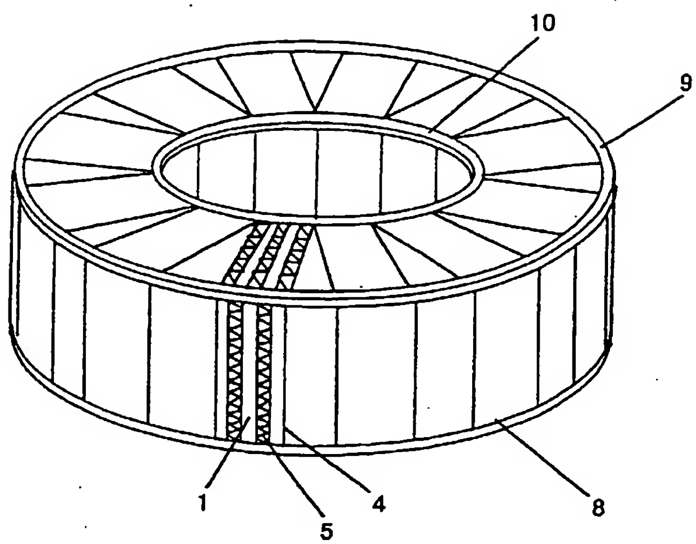

FIG. 6

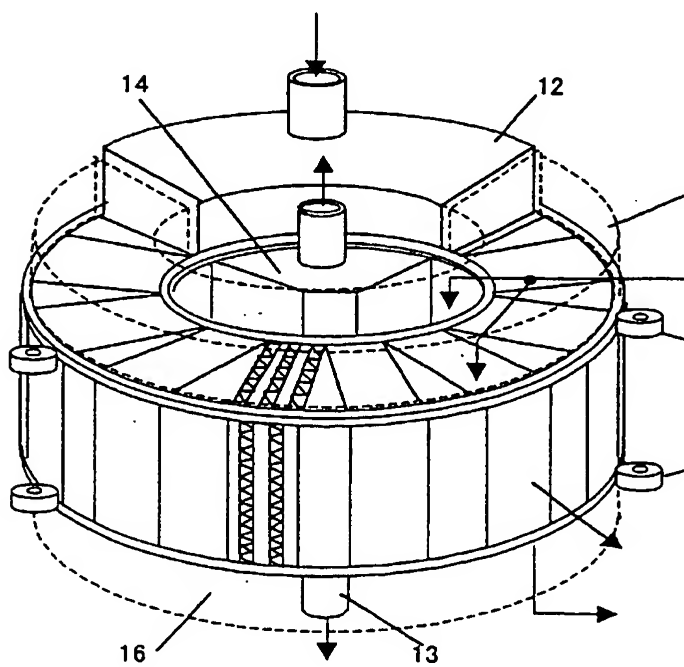

FIG. 7

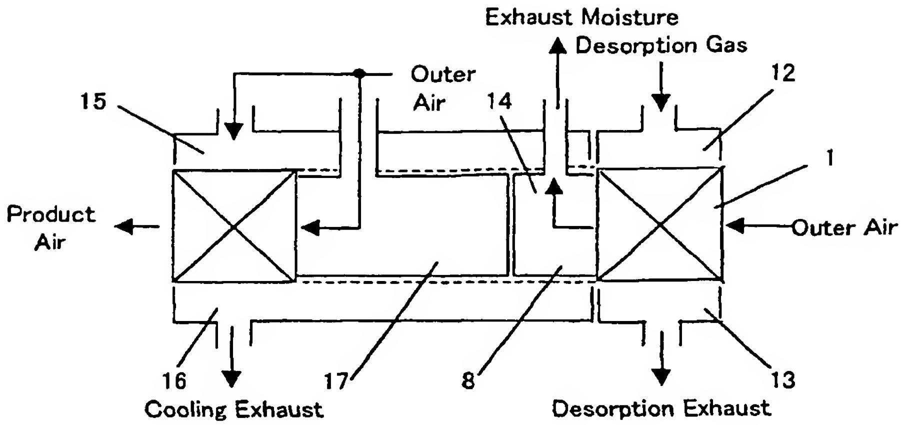
Exhaust Moisture
Desorption Gas
Outer Air
14
15
12
1
Product Air
Outer Air
16
17
8
13
Cooling Exhaust
Desorption Exhaust

FIG. 8

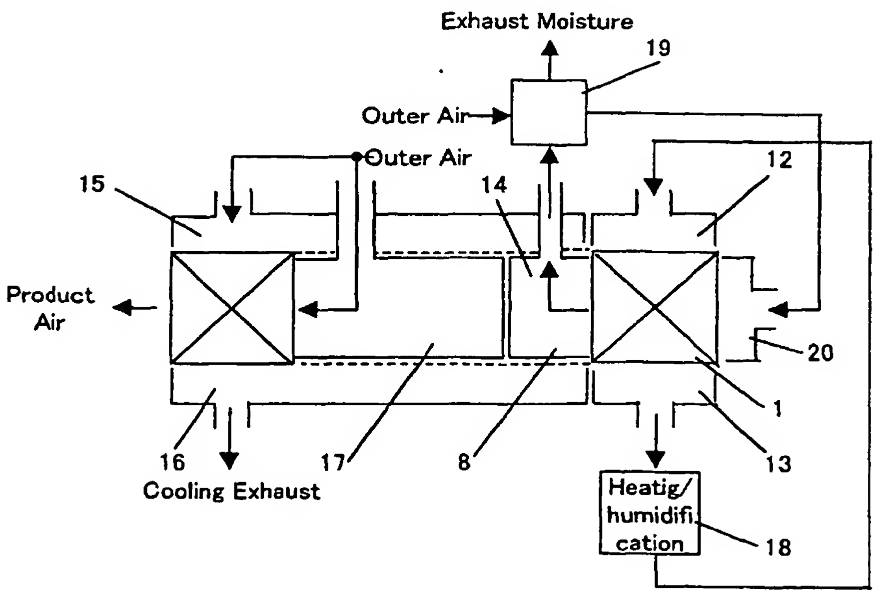
Exhaust Moisture
19
Outer Air
Outer Air
15
14
12
Product Air
20
1
16
17
8
13
Cooling Exhaust
Heatig/ humidifi cation
18

FIG. 9